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Descriptions of Fleas from Northern Canada (Siphonaptera)[1]

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Three species and one subspecies of fleas, all belonging to the Ceratophyllidae, are described and figured in this paper. One of the species, formerly known only from Siberia, and imperfectly described, is redescribed, and recorded from Yukon Territory. The remaining two species and the subspecies are believed to be new to science.

Ceratophyllus scopulorum new species

(Figs. 1-7)

A medium sized, pale-yellowish species. In Holland's key (1951, pp. 287-288) males would stop at couplet 7 as the movable process (F) is widest in the middle rather than in the proximal or the distal half. Distinguishable from all other known species by the fixed process (Fig. 5, P), which is about six times as long as broad, almost attains length of F, and is longer and/or narrower than in other species.

Superficially resembling *C. farreni* Roths. (European), which has P about half as long as F; and *C. sinicus* Jord. (Oriental), which also has P relatively short, and F with about 5 long setae on the posterior margin rather than two or three.

Females would key to *petrochelidoni* Wagn. or *idius* Jord. and Roths., but are distinguishable from these (and from *farreni*) by a heavy, ridge-like sclerotization around the vertex of the sinus of sternum VII; occasional specimens of *petrochelidoni* with sternum VII sclerotized in the vicinity of the sinus (Holland, 1951, Fig. 10, h, i) but not with a raised, pigmented ridge. *C. sinicus* has sternum VII entire.

Male

Head with ocular row of three long setae and frontal row of about five thinner, shorter setae. Clypeal tubercle conspicuous, and located well below middle placoid of the preantennal region. Eye large and deeply pigmented. Second antennal segment with long marginal bristles.

Pronotum with about 14-15 long, heavy spines per side. Mesonotum with about six slender pseudosetae per side. Collar of metanotum reduced, with apical spinelets weak or lacking (Fig. 1). Remaining thoracic elements typical of those of most species of *Ceratophyllus* and related genera (cf. next species); pleural ridge of metathorax strongly developed, terminating dorsally in a bulb-like expansion that is enclosed by a well-developed pleural arch.

Legs well developed; posterior margin of hind tibia with stout setae well developed except for the first, third, and sixth pairs (Fig. 2).

Only the anterior two or three abdominal spiracles appearing doubled up. Typical abdominal terga each with a row of 7 or 8 long setae reaching approximately to the spiracle. A shorter row, of 4-7 shorter setae, located anteriorly. Apical spinelets on abdominal terga as follows: I, 2 (rarely 1) per side; II, 2; III, 2 (rarely 1); IV, 1 (sometimes 2; rarely 0).

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One long antepygidial seta, with one or two minute hairs at its base. Tergum VIII with about 12 setae along the dorsal margin and about 6 disposed laterally (Fig. 3). An extensive spiculose area on the dorsal inner surface of tergum VIII, the ventral limits of this area rather sharply marked. Sternum VIII long and rod-like, with nearly parallel margins. Apically, on either side, about four or five posteriorly directed setae and a well-developed membranous flap, fringed posteriorly. Clasper with fixed process (P) excessively long and slender (Figs. 4 and 5). Acetabular setae two, and unusual in that the dorsal seta is longer than the ventral. Length of movable process (F) about four times width and slightly exceeding that of P. Anterior and posterior margins of F slightly convex. On anterior margin of F, a small sclerotized process, engaging in a depression on P; on posterior margin two, sometimes three, conspicuous setae, located near the mid-point (Fig. 5). Smaller setae as shown. Dorsal arm of sternum IX with nearly parallel margins; without pronounced broadening near the mid-point. Ventral (posterior) arm with proximal lobe unusually long, and armed ventrally with a fringe of setae. Distal lobe with ventral setae as shown, and expanded apically. Penis rods and apodemal rod of sternum IX coiled up, completing more than one full convolution. Crochet of aedeagus long, and tapering apically to a rounded point.

Female

Chaetotaxy of head as in the male, but frontal row of setae somewhat weaker, usually with three or four slender setae.

Pronotal comb with about 16-17 spines per side. Other details of thorax and pregenital segments of abdomen approximately as in the male.

Three antepygidial setae, the second very long, and the first and third very short, seldom exceeding one-fourth the length of the second. Tergum VIII with more than 20 medium or longish setae ventro-laterally; about 5-6 short, stout steae inserted on the inner surface, near the posterior margin. Anal stylet with a long apical seta, and two short setae; length of stylet slightly more than twice breadth. Sternum VII with a pronounced lobe and sinus (Fig. 6), the area bordering the sinus being heavily sclerotized. The shape of sternum VII remarkably uniform in the series examined, thereby differing markedly from that of *C. petrochelidoni* Wagn., which exhibits great variation (Holland, 1951, Fig. 10). Spermatheca of the narrow type, with the head, or body, sausage-shaped; the tail, or appendix, terminating apically in a sclerotized papilla (Fig. 7). Duct of spermatheca long and unsclerotized; proximal end of the blind duct, or ductus obturatus, sclerotized for about half its length. Bursa copulatrix with a dorsal marginal sclerotization at the orifices of the ducts (Fig. 6).

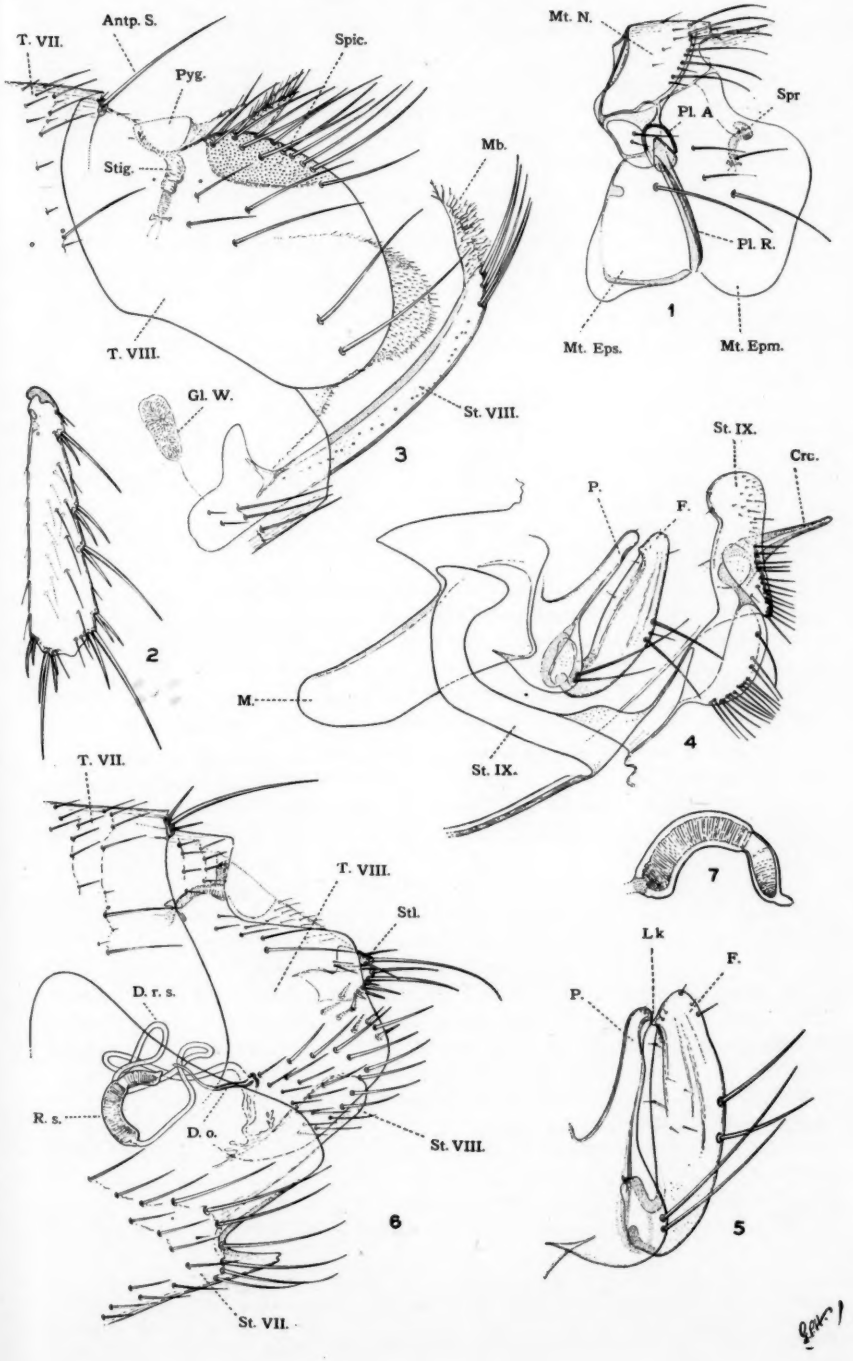
Size (mounted specimens): ♂, average 2.85 mm. (2.4-3.2); ♀, average 2.9 mm. (2.1-3.4).

Holotype.— ♂, Rampart House, Yukon Territory, August 10, 1951, collected from the nests of cliff swallows, *Petrochelidon pyrrhonata albifrons* (Rafinesque), by J. E. H. Martin; No. 5999 in the Canadian National Collection, Ottawa.

Allotype.— ♀, same data.

Paratypes.—25 ♂ ♂, 25 ♀ ♀ on slides; many additional specimens in alcohol; same data.

Figs. 1-7. ***Ceratophyllus scopulorum*** **n. sp. 1, Metathorax of male. 2, Hind tibia of male. 3, Terminal abdominal segments of male. 4, Genitalia of male. 5, Enlarged detail of clasper processes. 6, Terminal abdominal segments and genitalia of female. 7, Detail of spermatheca.**


T. VII.
Antp. S.
Pyg.
Spic.
Stig.
Mb.
T. VIII.
Gl. W.
St. VIII.
3
2
Mt. N.
Spr
Pl. A
Pl. R.
1
Mt. Eps.
Mt. Epm.
St. IX.
Crc.
P.
F.
M.
St. IX.
4
T. VII.
T. VIII.
Stl.
D. r. s.
R. s.
D. o.
St. VIII.
6
St. VII.
7
Lk
F.
P.
5

Ceratophyllus arcuegens new species

(Figs. 8-15)

A medium-sized species; light, with dark areas on each abdominal segment. Separable from all other known Nearctic species of *Ceratophyllus* by the absence of a pleural arch in the metathorax; pleural ridge (Fig. 9) lacking the expanded "head" found in the species possessing such an arch, in this respect agreeing with three Old World species, *C. rusticus* Wagn., *C. caliotes* Jord., and *C. orites* Jord. Evidently a rather sedentary species as indicated by the rather large and deep abdomen, as well as by some reduction of the legs and thorax; a crawler rather than a jumper. A marked difference in degree of sclerotization between the anterior and posterior parts of each abdominal tergum and sternum, giving the effect of dark and light vertical bands (lateral aspect) dorsally and ventrally on each segment in specimens in alcohol as well as in mounted ones.

Male

Clypeal tubercle moderately developed, and located somewhat more dorsad than is usual in the genus, nearly on a level with the second preantennal placoid (Fig. 8). Eye large and well pigmented. Ocular row of three long setae and frontal row of about three shorter setae. Postantennal region with one long seta inserted at about the mid-point of the margin of the antennal fossa, with sometimes a smaller seta above it, and another anterad. Rostrum approximately attaining fore trochanter.

Pronotal comb with about 15 spines per side, none of these equalling the pronotum in length. Mesonotum with about 6 pseudosetae per side. Metanotum usually with one slender spinelet per side; collar of metanotum reduced. Legs somewhat smaller and weaker than in *C. scopulorum* and other Nearctic species of *Ceratophyllus* and showing some reduction in vestiture. Hind tibia with only four pairs of well-developed bristles along the posterior margin (Fig. 10).

Typical abdominal terga each with a row of about 7 long, slender setae. A row of shorter setae located anteriorly which on terga V to VII may be lacking or reduced to only one or two short bristles. Apical spinelets on abdominal terga as follows: I, 2 (rarely 3) per side; II, 2 (rarely 3); III, 2 (sometimes 1); IV, 1 (rarely 0 or 2).

One long antepygidial seta; sometimes with a minute hair at its base. Tergum VIII with about 14 setae along the dorsal margin; about three inserted dorso-laterally, and two ventro-laterally; posterior margin with a shallow sinus. Spiculose area of tergum VIII extensive, but with the spicules not so pronounced as in the preceding species. Sternum VIII long and rod-like (Fig. 11), with about three long setae on each side, apically. An apical membranous appendage extending dorsally at the apex of sternum VIII, its anterior margin supported by a stiff rim and its posterior margin fringed; this membrane best examined in a temporary fluid mount (as illustrated), usually becoming distorted in permanent preparations. Clasper with fixed process (P) short and thumblike, with an apical groove which, when engaged by a sclerotized projection on the anterior margin of the movable process, forms a "lock". Two long, equal, acetabular setae. Movable process (F) about three times as long as greatest breadth; broadest distally. Its posterior margin, which is armed with three long and one short

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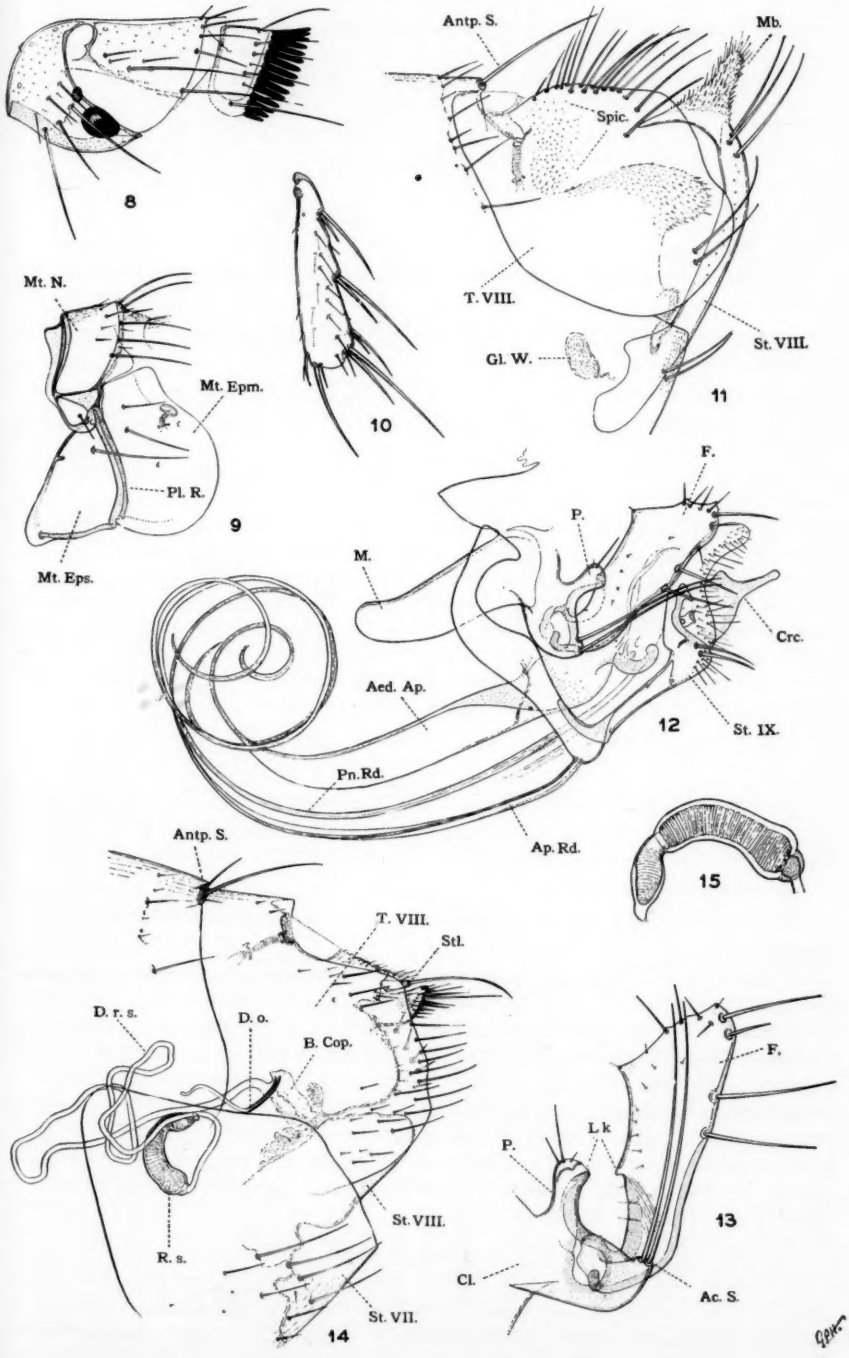
Figs. 8-15. *Ceratophyllus arcuegens* n. sp. 8, Head and pronotum of male. 9, Metathorax of male (holotype). 10, Hind tibia of male. 11, Terminal abdominal segments of male (holotype). 12, Genitalia of male (holotype). 13, Enlarged detail of clasper processes, showing "lock". 14, Terminal abdominal segments and genitalia of female (allotype). 15, Detail of spermatheca.


8
Antp. S.
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T. VIII.
St. VIII.
Gl. W.
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Mt. N.
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Mt. Eps.
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F.
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Crc.
Aed. Ap.
12
St. IX.
Pn.Rd.
Ap. Rd.
15
Antp. S.
T. VIII.
Stl.
D. r. s.
D. o.
B. Cop.
St. VIII.
R. s.
St. VII.
14
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P.
L k
13
Cl.
Ac. S.

setae, almost straight; anterior margin slightly concave and distal margin produced into a number of points (Figs. 12 and 13). Dorsal arm of sternum IX broad in the middle. Ventral arm with proximal lobe bearing two stout, curved setae (as in *C. orites*) and a number of slender setae; distal lobe tapering apically and bearing a ventral row of setae. Penis rods and apodemal rod of sternum IX coiled up, completing more than one convolution. Crochet of aedeagus broad proximally, tapering rapidly distally, and drawn out into a long, straight process, rounded apically (Fig. 12).

Female

Details of head essentially as in the male, except for the usual sexual differences.

Pronotal spines, and apical spinelets of abdominal terga, approximately as in the male.

Three antepygidial setae, the second long and the first and third short (Fig. 14), their lengths varying much in individuals. Tergum VIII with fewer than 20 medium or short setae ventro-laterally; about 6 stout setae inserted on the posterior, inner surface. Anal stylet with a long apical seta and with or without a shorter seta ventrally, at the base of this; more rarely, two basal setae, one dorsad and one ventrad. Length of stylet slightly more than twice breadth. Sternum VII with posterior margin entire, and about 8-10 slender setae, arranged in two rows. Membranous sternum IX clearly visible above genital opening; armed with about 8 almost spiniform, small setae. Spermatheca characteristic of *Ceratophyllus* except that the head, or body, is expanded proximally (Fig. 15), with a further bulbous expansion in the cribiform area. Duct of spermatheca long and tortuous; ductus obturatus sclerotized in its proximal half. Bursa copulatrix without a sclerotized section.

Size (mounted specimens): ♂, average 2.8 mm. (2.5-3.1); ♀, average 3.15 mm. (3.0-3.4).

Holotype.— ♂, Rampart House, Yukon Territory, 10.VIII.51, collected from the nests of *Petrochelidon pyrrhonata albifrons* (Rafinesque), by J. E. H. Martin; No. 6000 in the Canadian National Collection, Ottawa.

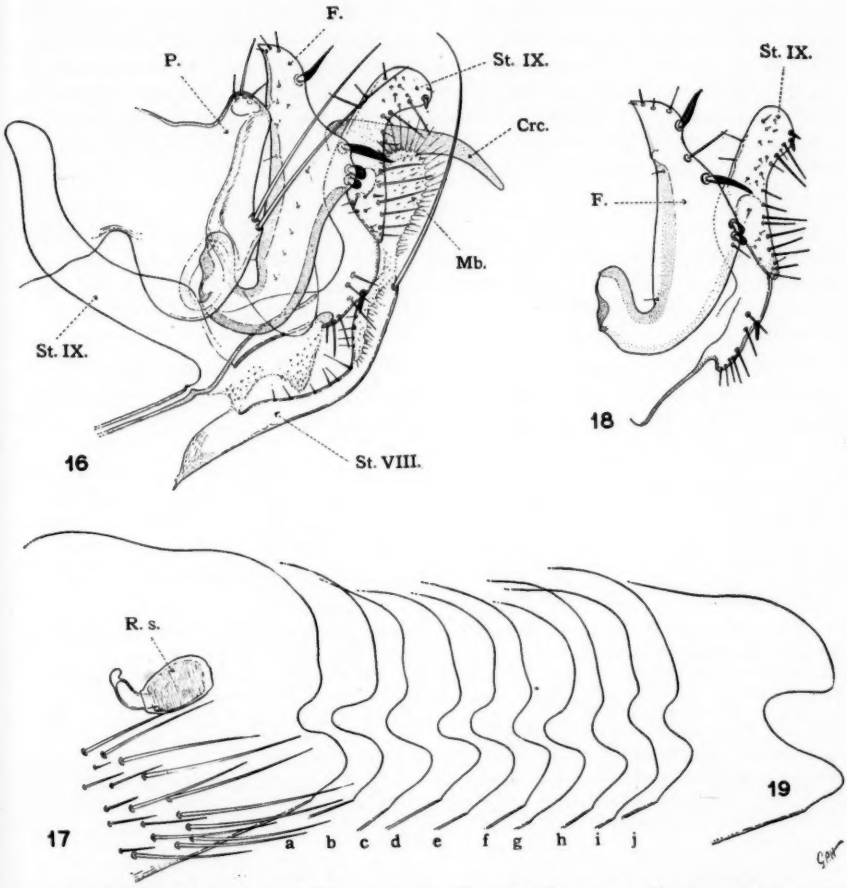
Allotype.— ♀, same data.

Paratypes.—13 ♂ ♂, 8 ♀ ♀ on slides; 1 ♂, 1 ♀ in alcohol; same data.

Comments

The discovery of *C. scopulorum* and *C. arcuegens* in cliff swallow nests occasioned some surprise, as *C. petrochelidoni* Wagn., the well-known flea of this bird, from central British Columbia to California, was the species expected. However, as the latter species was not represented in the collections made at Rampart House, it appears that *Petrochelidon* supports at least three species of *Ceratophyllus*, which occupy different parts of its range. Swallows and martins are unusual among birds in that a number of species are infested by fleas that are very host specific; many (not all) other bird fleas are more cosmopolitan in their associations and in some cases, apparently, are more concerned with a type of habitat than with a particular species of host.

Of New World swallow fleas, besides those infesting *Petrochelidon* spp., *Ceratophyllus riparius* Jord. and Roths. and *C. celsus* Jord. favour the bank swallow, *Riparia riparia* (Linn.), whereas *C. idius* Jord. and Roths. is most frequently found in the nests of the purple martin, *Progne subis* (Linn.), and the tree swallow, *Iridoprocne bicolor* (Vieillot). A number of Old World species,



Figs. 16-19. *Malaraeus penicilliger* ssp. 16, *M. p. athabascae* n. ssp. Genitalia of male (holotype). 17, Sternum VII and spermatheca of female (a, allotype; b-j, paratypes). 18, *M. p. dissimilis* Jord. Movable process, and distal lobe of sternum IX of male (paratype; from Rapids, Alaska). 19, Sternum VII of female (paratype; Rapids, Alaska).

including *C. hirundinis* Curtis, *C. farreni* Roths., *C. rusticus* Wagn., *C. styx* Roths., *C. caliotes* Jord., *C. orites* Jord., and *C. numidus* Jord. and Roths., infest various swallows or martins occurring in that region.

***Malaraeus penicilliger athabascae* new subspecies**

(Figs. 16-19)

Malaraeus penicilliger dissimilis, Holland, 1949 (*partim*), p. 155 (*nec* Jordan, 1938).

Reliably separable from *M. penicilliger dissimilis* Jord., the only subspecies of *M. penicilliger* (Grube) at present described from the Nearctic Region, by details of the male genitalia; not so reliably by the characters of the female. Head, thorax, legs, and pregenital segments of abdomen apparently not differing significantly from those of *dissimilis*.

Male

Movable process (F) of clasper long, narrow, and with the posterior margin, below the spiniforms, more or less concave (Fig. 16); not convex as in *dissimilis*

(Fig. 18). The second long spiniform on F close to the two short, blunt spiniforms; more widely separated in *dissimilis*. Distal lobe of ventral arm of sternum IX curving ventrad, and with the angle near the terminal spiniform rounded-acute rather than bluntly obtuse as in *dissimilis* and all other subspecies of *penicilliger* known to the writer. Crochet of aedeagus very long and slender. Sternum VIII curving dorsad rather abruptly, and terminated apically by a long seta and membranous appendage as shown (Fig. 16).

Female

Sternum VII only moderately incised (Fig. 17), apparently never deeply, as is usual in *dissimilis* (Fig. 19). Although no available specimen of *athabascae* has a deep sinus, occasional specimens of *dissimilis* have shallow sinuses, and might be confused. The spermatheca and other structures of the female genitalia not differing from those of *dissimilis*.

Holotype.— ♂, Fort Smith, Northwest Territories, 29.IV.48, collected from Athabasca red-backed mouse, *Clethrionomys gapperi athabascae* (Preble), by Wm. A. Fuller; No. 6001 in the Canadian National Collection, Ottawa.

Allotype.— ♀, same data.

Paratypes.—4 ♂ ♂, 14 ♀ ♀ as follows: same data as holotype, 2 ♂ ♂, 4 ♀ ♀; same locality and host, but collected on the following dates—22.XI.47, 1 ♂, 3 ♀ ♀; 28.IV.48, 5 ♀ ♀. Chipewyan, Alberta, ex *Clethrionomys g. athabascae*, 21.VI.45, 1 ♂; 31.VIII.45, 1 ♀. Wood Buffalo Park, Alberta, ex *C. g. athabascae*, 2.VII.47, 1 ♀; all collected by W. A. Fuller.

The following material also appears to be referable to this subspecies: Churchill, Manitoba, 7.VII.49, ex *Microtus pennsylvanicus* ssp., 1 ♂ (J. B. Wallis); Wabowden, Man., 21-24.V.49, ex *Clethrionomys gapperi* ssp., 1 ♂, 5 ♀ ♀ (J.B.W.); Pikwitonei, Man., 26-31.V.49, ex *Clethrionomys gapperi* ssp., 1 ♂, 2 ♀ ♀ (J.B.W.); Gillam, Man., 5-10.VI.49, ex *Clethrionomys gapperi* ssp., 2 ♂ ♂, 7 ♀ ♀; 20.VII.49, ex *Synaptomys borealis* ssp., 2 ♀ ♀ (J.B.W.); Great Whale River, Que., 20.VI.49, ex *Clethrionomys gapperi* ssp., 1 ♀; 19.VIII.49, ex *Microtus* sp., 1 ♂; 9.IX.49, ex *Microtus* sp., 1 ♀ (J. R. Vockeroth); Goose Bay, Labrador, 25.IX.47, ex *Clethrionomys gapperi proteus* (Bangs), 1 ♂, 4 ♀ ♀ (R. Traub and D. Koelle); 18.X.47, ex *C. g. proteus*, 1 ♂, 7 ♀ ♀ (R. Traub and D. Johnson); 6 miles S. of Ft. Chimo, Ungava, Quebec, 3.X.47, ex *Clethrionomys gapperi ungava* (Bailey), 1 ♀ (R. Traub).

Comments

An assemblage of fleas, widely distributed in the Holarctic Region on microtines, especially of the genus *Clethrionomys*, are at present considered to represent subspecies of *Malaraeus penicilliger* (Grube). The status of most of these is not well understood, and studies of adequate material in the future may indicate that some of the segregates are species. The one representative hitherto described from the New World, *M. penicilliger dissimilis* Jordan, was recorded by the original author from various localities in Alaska and northern British Columbia, from several species of mice. The present writer (1944, p. 246; 1949, p. 155) supplied a few records from British Columbia, Alberta, and Northwest Territories (of which the specimens from Chipewyan, Alberta, are referable to *M. p. athabascae*, described above). Fairly extensive collections of these fleas indicate that the forms are allopatric, but whether species or subspecies cannot be decided with confidence. The subspecific interpretation is adopted here for expediency, following traditional treatment of the group. The differences between *dissimilis* and *athabascae* are striking, especially in the male, and it would be tempting to consider the latter as specifically distinct. This should not be done, however, before the Palaearctic representatives and/or relatives of *penicilliger* are reviewed, a task the author is not prepared to undertake at this time, other than to point out in passing that the British form, listed for many years as *M. penicilliger penicilliger*,

differs strikingly, in both sexes, from specimens examined from various Siberian localities and from Wagner's published figure (1898, Plate 8, Fig. 6) of the type of the species (which was described from Turuchansk, Siberia) and warrants subspecific recognition at least. This will require the revival of *P.* [*i.e.*, *Pulex*] *mustelae* Dale, 1878, synonymized with *penicilliger* Grube by Rothschild (1920, p. 77). This flea, then, should be known as *Malaraeus penicilliger mustelae* (Dale) until the '*penicilliger* group' can be studied on a broad basis.

As recognized here, *M. p. dissimilis* occurs abundantly through Alaska, Yukon Territory, northern British Columbia, and western District of Mackenzie, where the favoured host appears to be *Clethrionomys rutilus dawsoni* (Merriam). *M. p. athabascae* extends eastward and southward from Great Slave Lake and occurs on *Clethrionomys gapperi* ssp. Collections from the critical area where the ranges of these two voles come together are not available.

The type series of *athabascae* is restricted to material from a relatively small area, as there are suggestions of further geographical variation in the limited collections available. This is particularly noticeable in the series from Goose Bay, Labrador, in which sternum VII has a shallow sinus and an additional, and very distinctive, indentation in the lobe above it, a condition not matched in the material from the Athabaska region. Again, proper analysis must await longer series.

***Monopsyllus tolli* (Wagner)**

(Figs. 20-25)

Ceratophyllus tolli Wagner, 1901, pp. 19-21; pl. 1, fig. 8.
Megabothris toli [sic!], Wagner, 1934, p. 262.
Monopsyllus (*Amonopsyllus*) *toli*, Ioff, 1936, p. 96; figs. 3, 14, 34, 44.
Monopsyllus anadyrus Jordan, 1937, pp. 288-289; figs. 72, 73. *New synonymy.*
Amonopsyllus anadyrus, Wagner, 1938, p. 9 [suggested *anadyrus* may be a synonym of "*toli*"].

Monopsyllus tolli was described from a single male collected at an unstated locality in Siberia, the host being unknown, although Wagner suggested that it might have been a flying squirrel. The description was accompanied by a very inadequate illustration of part of the genitalia. However, the same specimen was sketched later, and more convincingly, by Ioff (1936, Figs. 3, 14, 34, 44).

Monopsyllus anadyrus was described from two females collected at Emma Harbour, East Siberia, ex *Ochotona hyperborea* (Pallas). Wagner (1938, p. 9) suggested that this might be a synonym of *tolli*. A small collection of fleas from Yukon Territory, Canada, ex *Ochotona collaris* (Nelson), confirms this view, the two males tallying fairly well with Ioff's figures of *tolli*, and the three females corresponding closely with Jordan's description and figures of *anadyrus*. Dr. K. Jordan (in litt.) concurs with this opinion. The Nearctic representative of the species may be subspecifically distinct, but, as the available material is so meagre, it is not possible to evaluate supposed differences between Nearctic and Palaearctic populations at this time.

A redescription of the species follows:—

A medium-sized, dark-brown species, most nearly resembling *M. ciliatus* (Baker) but easily distinguished in both sexes by the larger number of pronotal spines: about 12 on each side in *tolli*; 9 in *ciliatus*.

Male

Head with ocular row of three long setae and frontal row of about 7 shorter setae (Fig. 20). Clypeal tubercle present and eye large and well pigmented. Bristles on second antennal segment short.

Pronotal comb with about 12 well-developed spines per side. Mesonotum

with 5-6 pseudosetae, and metanotum with one apical spinelet, per side. Legs well developed; tibiae and tarsi heavily bristled.

Anterior abdominal terga with one or two apical spinelets per side, and two rows of setae.

One long antepygidial seta, with two very short setae at its base. Tergum VIII with a row of four strong setae along the dorsal margin, and about six disposed laterally (Fig. 21). Sternum VIII rod-like, tapering apically, with about three terminal setae and a small membranous appendage; a scattering of short setae ventrally. Manubrium of clasper tapering to a blunt point. Fixed process (P) of clasper strong and curved slightly caudad; two or three long acetabular setae. Movable process (F) sub-triangular, exceeding P; with a slender seta and two blunt spiniforms at the posterior angle, and a long, straight, pigmented seta on the posterior margin. The position of this seta and the shape of P and F differ in the two males available (Figs. 22 and 23). Aedeagal apodeme with a long apical extension, curving dorsally. Penis rods and apodemal rod not completing a full convolution. Crochet tapering to a blunt point. Sternum IX with the dorsal arm expanded apically, and with a slight swelling on the posterior margin, at the mid-point. Distal lobe of ventral arm very broad, with only a few slender setae.

Female

Well described by Jordan (1937, pp. 288-289).

Recognizable at once by the distinctive spermatheca (Fig. 25), of which the length of the body is about three times its breadth, the sides being nearly parallel. Sternum VII with a rounded lobe and sinus (Fig. 24) and about 6 long, and 10 shorter, setae.

The species is represented in the Canadian National Collection by the following material: Tepee Lake, Kluane Game Sanctuary, Yukon Territory, 15.I.51, ex *Ochotona collaris* (Nelson), 2 ♂♂, 3 ♀♀, collected by A. W. F. Banfield.

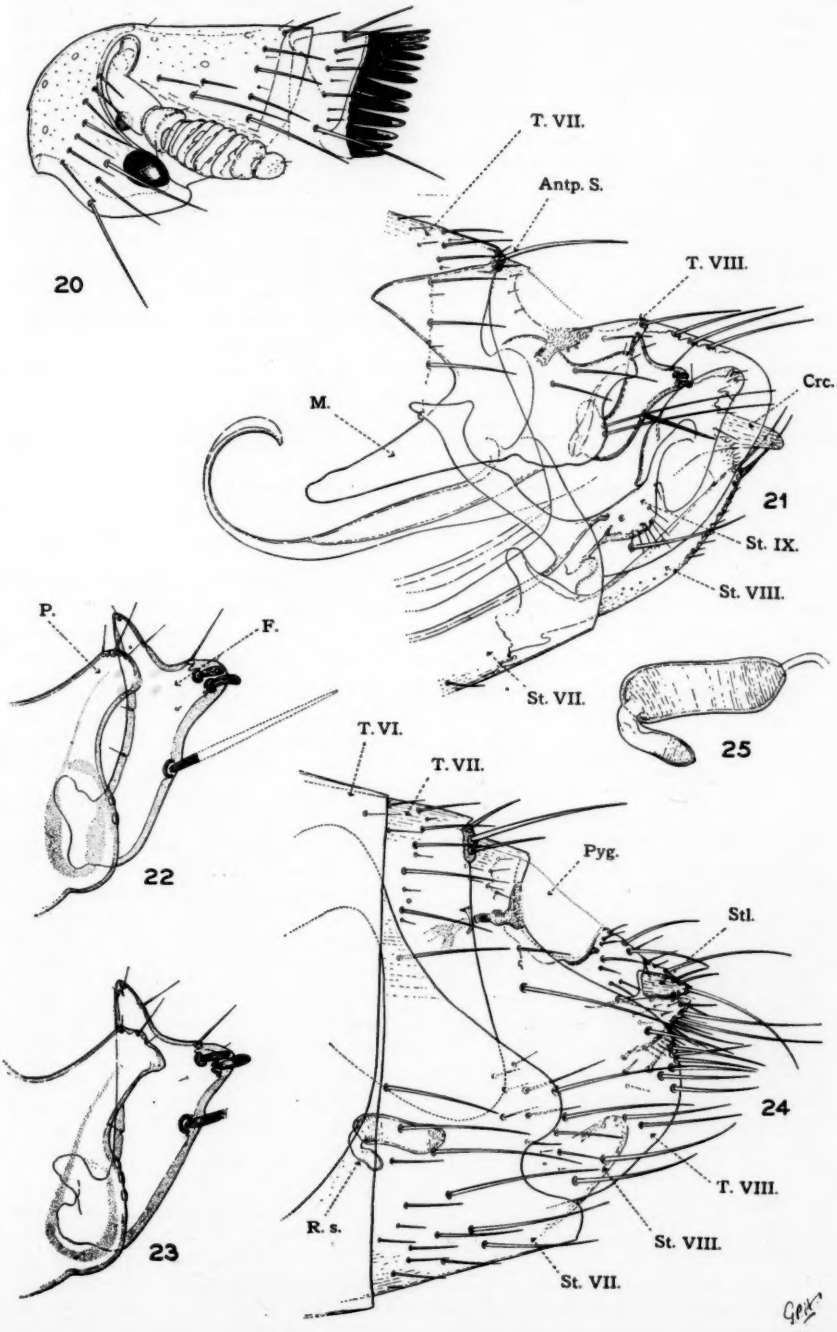
Acknowledgments

The writer is indebted to Dr. Karl Jordan, F.R.S., of the Zoological Museum at Tring, Herts., England, for his opinions and comments on the material described in this paper. Mr. W. A. Fuller and Captain A. W. F. Banfield, both of the Canadian Wildlife Service, Department of Resources and Development, kindly supplied the specimens from Fort Smith, N.W.T., and Tepee Lake, Y.T., on which the descriptions of *Malaraeus penicilliger athabascae* and *Monopsyllus tolli* were based. Lt. Col. Robert Traub of the Army Medical Service Graduate School, Washington, D.C., permitted the use of his material of *M. p. athabascae* from Quebec and Labrador. The remaining collectors named, Messrs J. R. Vockeroth, J. E. H. Martin, and J. B. Wallis, are officers who were attached to parties of the Northern Insect Survey, a joint project of the Division of Entomology and the Defence Research Board, Department of National Defence. To all of these, the writer expresses his thanks.

Abbreviations Used in Illustrations

Ac.S., acetabular setae; Aed.Ap., aedeagal apodeme; Antp.S., antepygidial setae; Ap.Rd., apodemal rod of sternum IX; B.Cop., bursa copulatrix; Cl., clasper; Crc., crochet; D.o., ductus obturatus; D.r.s., ductus receptaculi seminis; F., movable process of clasper; Gl.W., gland of

Figs. 20-25. *Monopsyllus tolli* (Wagner). 20, Head and pronotum of male (Tepee Lake, Yukon). 21, Terminal segments of abdomen and genitalia of male. 22-23, Enlarged detail of clasper processes of two males. 24, Terminal abdominal segments of female. 25, Detail of spermatheca.


T. VII.
Antp. S.
T. VIII.
Crc.
M.
St. IX.
St. VIII.
St. VII.
P.
F.
T. VI.
T. VII.
Pyg.
Stl.
R. s.
T. VIII.
St. VIII.
St. VII.
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Wagner; Lk., "lock" of clasper; M., manubrium; Mb., membranous appendage; Mt.Epm., metepimere; Mt.Eps., metepisternum; Mt.N., metanotum; P., fixed process of clasper; Pl.A., pleural arch; Pl.R., pleural ridge; Pn.Rd., penis rods Pyg., sensilium; R.s., spermatheca; Spic., spiculose area of tergum VIII; Spr., spiracle; St., abdominal sternum; Stig., spiracular opening of tergum VIII; Stl., anal stylet; T., abdominal tergum.

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Parthenogenesis in the Mealybug, *Phenacoccus solani* Ferris

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Reproduction in the Pseudococcidae is usually regarded as being predominantly, if not exclusively, bisexual, though Ferris (1950) has pointed out that within the family as defined by him males are known for only a small percentage of the species described to date. Detailed biological observations have been restricted to those members of considerable economic importance and in regard to reproductive habits there are few specific references in the literature. Hough (1922) in his account of the life history of the clover root mealybug *Chnaurococcus trifolii* (Forbes) Ferris, stated that no males were seen throughout the period of the observations. James (1937) made a comprehensive study of the reproduction of *Planococcus citri* (Risso) Ferris, *Pseudococcus maritimus* (Ehrh) Ferris, *P. gahani* Green, *P. adonidum* (Linn.) Ferris, and *Trionymus peregrinus* Green, and found that parthenogenesis did not occur in any of these species. This confirmed conclusions of earlier workers with *Pl. citri* (Schrader 1923, Sutherland 1932), and with *P. gahani* and *Phenacoccus gossypii* Twns & Ckll. (Basinger 1934). However, Myers (1932) reported parthenogenesis in some of his experiments with *Pl. citri* but his procedure of isolating females from the cultures after the second moult is clearly open to criticism. Strickland (1951) observed a strong parthenogenetic habit in females of the cacao mealybug *P. njalensis* Laing in the Gold Coast, and remarked that such reproduction was limited in some way since one virgin female lived sixty-five days after maturity without producing eggs. Bodenheimer (1951) considered that parthenogenesis had not been conclusively proved to occur in the genus *Pseudococcus*, and

attributed such reported occurrences to faulty procedure of the type demonstrated in his own experiments with *Pl. citri.*

During laboratory production of some dozen species of primary parasites of the commoner Californian mealybugs for possible use against the cacao mealybug complex in West Africa, it was noticed that in the stock jars of *Phenacoccus solani* Ferris there was a complete absence of the characteristic male cocoons usually spun on the top, bottom, and sides of each container. This obvious contrast with conditions in the jars of *Pl. citri*, *P. adonidum*, *P. gahani*, *P. maritimus*, and *Ph. gossypii*, prompted a search for living or dead male adults in the *Ph. solani* jars. A careful examination was made of some twenty small and large containers carrying tens of thousands of mealybugs of all ages on sprouting potatoes and not a single male was found. It was therefore tentatively concluded that the species in question was reproducing parthenogenetically since the presence of males could scarcely be overlooked unless it was unjustified to assume that they would conform in morphology to the types characteristic of the family. The unusual, and also puzzling feature was the failure to find some males in cultures containing hundreds of mature females actively throwing crawlers.

This fact, and the strong evidence against the occurrence of parthenogenesis in the Pseudococcidae presented by earlier workers, indicated the need for experimental confirmation of the habit in the present species. The following observations have therefore been made.

Twenty-five females were taken from the above production containers and isolated in individual breeding jars each containing a small sprouting potato. On the basis of size and the absence of the rudimentary ovisac, these females were considered to have not started oviposition but to be very near maturity. The generation of crawlers produced by them was allowed to develop and the potatoes and containers thoroughly examined for males. None was found. Fecundity of the females varied from 1 to 98, with an average number of progeny per female of 31.5.

Parallel with the foregoing experiment clean, smooth potatoes with a single sprout about 2″ long were selected and small breeding cells set up over the sprouts by the use of sections of one inch diameter plastic tubing capped by corks. In each such cell a single, recently emerged crawler of *Ph. solani* was placed on the sprout. These first instars were removed from beneath the bodies of females taken from the stock breeding jars. For all practical purposes this is the youngest age it is possible to obtain since this mealybug is ovo-viviparous and periodically produces small numbers of young which remain under the female's body for the first few days of life. Eggs are extruded into the few wax threads secreted at the end of the abdomen to form a very rudimentary pad or ovisac. Eclosion occurs some hours later, the egg shells often being retained in the wax threads. Removal of eggs without injury from this pad is very difficult, and for this reason young first instars were chosen for the experiment. There is appreciable mortality of crawlers in this species even when left undisturbed on the host plant, and to allow for this delicacy of the first instars well over one hundred crawlers were isolated in individual cells. Of these initial specimens twenty were observed some days later as feeding second instars, and they were set aside to develop to maturity.

All twenty specimens were female and each proceeded to throw crawlers. Fecundity in this series varied from 7 to 65, the average number of progeny per

female being 34. (These figures and those in the first experiment are counts of second and older instars; the natural mortality of first instars referred to above was ignored as no accurate record could be made of this under the experimental technique adopted.) Most of these progeny in turn matured to females which produced young. In both generations from 25 to 50% of all offspring attaining the second instar entered a resting phase in that stage and remained in that condition throughout the course of the observations. The presence of such instars in apparent diapause is also common in the stock breeding jars and many such specimens do not resume feeding but slowly shrivel and die. No explanation can be offered for this behaviour, and any attempt to relate it to the parthenogenetic habit would be simply speculative.[1] An extensive biological and cytological study of this mealybug would be instructive.

Since the initial observation of the absence of males, the stock cultures have been propagated through four generations. In the controlled experiments the mealybug has reproduced parthenogenetically for two generations to date (Feb. 15). As far as the writer is aware, no comparable behaviour in mealybug reproduction has ever been reported. It is noteworthy that no males have been recorded for this species although it is fairly common on potato, etc. under field and laboratory conditions in California and other western states. Professor G. F. Ferris of Stanford University and various staff members of the University of California have been consulted on this point. The mealybug's occurrence as an occasional insectary pest on sprouting potatoes used for the propagation of other coccids such as black scale, *Saissetia oleae* Bern., (Flanders 1944) may in large measure be due to the type of reproduction demonstrated above. Observations are being continued to determine if this parthenogenesis is of a constant or facultative thelyotokous type.

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[1]There is some suggestion that the phenomenon is a seasonal one associated with temperature but the evidence for this is not conclusive.

A New Species of *Scaphytopius* (*Cloanthanus*), with a Key to the Canadian Species (Homoptera: Cicadellidae)[1]

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The following is a description of a new species of leafhopper from Eastern Canada of the subgenus *Cloanthanus* of the genus *Scaphytopius*. A key to the known Canadian species of *Cloanthanus* is included. Two of these species, *angustatus* (Osb.) and *argutus* DeL., do not appear to have been recorded previously for Canada. The key is based primarily on structures of the male genitalia, as these show the most reliable specific characters. External characters of colour, markings, and structure are often unreliable, because of the variation that occurs. There is occasionally some variation in the genitalic characters, notably in the degrees of curvature of the paraphyses, but the general shape of each structure is sufficiently constant to provide reliable specific characters. This subgenus, which was revised by Hepner (1947), is poorly represented in Canada, as the majority of the species have southerly distributions in North America. The common Canadian species is *acutus* (Say), followed by *latus* (Baker); the remaining species are more restricted in their ranges and distributions in Canada.

***Scaphytopius* (*Cloanthanus*) *sarissus* n. sp.**

Fig. 1

Length: ♂, 4.4 mm.; ♀, 4.8 mm. Vertex fully one and one-half times as long as wide between the eyes in male, nearly twice as long as wide between the eyes in female; anterior margins straight or slightly convex to a sharp apex; wedge one-quarter to one-third length of vertex. Aedoeagus moderately short, strongly curved, shaft slightly narrowed beyond middle in lateral view; paraphyses long, slender, crossing each other beyond middle and then strongly curved downward and anteriorly, each weakly flattened on apical third, and with apex bifid into a straight spine almost in line with shaft and a shorter, lateral spine at right angles to shaft. Seventh sternite of female with postero-lateral margins evenly curved, sometimes with indications of a small median notch.

Colour fulvous brown. Vertex with numerous small, irregular, yellowish irrorations, with wedge yellowish, and with a narrow, pale line, often broken, along anterior margin. Face yellowish to yellowish-fulvous, more or less irrorated fuscous below and behind the eyes and in the region of the sharksmouth. Pronotum closely irrorated yellowish, some of the yellowish markings occasionally more or less confluent to form indications of irregular, broken, longitudinal bands. Scutellum irrorated yellowish, sometimes largely yellowish, with white spots at each end of transverse impression, at apex, and frequently at basal corners. Fore wing semi-hyaline light fulvous, with numerous milky areoles, and with veins brownish becoming fuscous toward apex and costa, darkest in males.

The distinctive feature of the species is the bifid apex of each paraphysis. In general form the genitalia resemble those of *cinnamoneus* (Osb.), but in that species each paraphysis is almost parallel-margined to a sharp apex (Fig. 5). In external characters the species resembles *cinnamoneus* and *magdalensis* (Prov.), but has a longer vertex which is more finely and evenly irrorated. There is some variation in colour and markings, and minor variation in the size of the lateral apical spine of each paraphysis.

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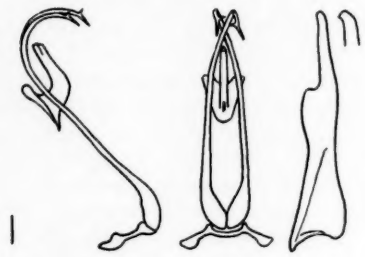
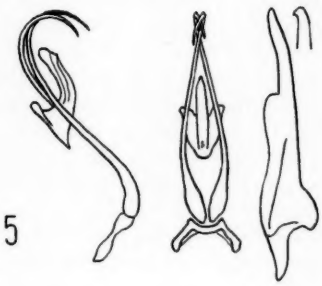
2Agricultural Research Officer.

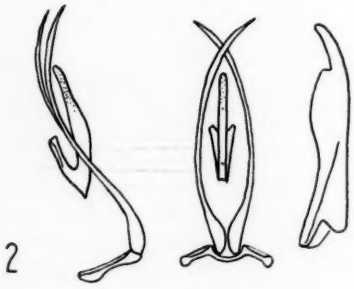
Holotype.— ♂, Mer Bleue, Ontario, August 9, 1932 (G. S. Walley). No. 5991 in the Canadian National Collection.

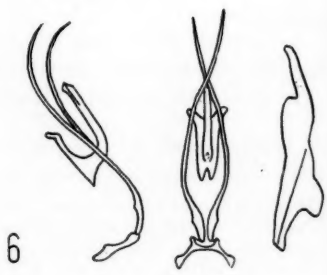
Allotype.— ♀, same data as holotype.

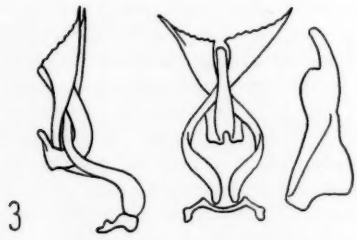
Paratypes.—24 ♂ and 11 ♀, Mer Bleue, Ontario, August 9, 1932 (G. S. Walley, and L. J. Milne); 7 ♂ and 13 ♀, same locality, September 3, 1929 (W. J. Brown, and L. J. Milne); 1 ♂ and 2 ♀, same locality, September 6, 1928 (G. S. Walley, G. H. Fisk, and J. A. Adams); 1 ♂, same locality, July 25, 1932 (L. J. Milne); 5 ♂ and 2 ♀, Auburn, Nova Scotia, August 4, 1934 (F. C. Gilliatt).

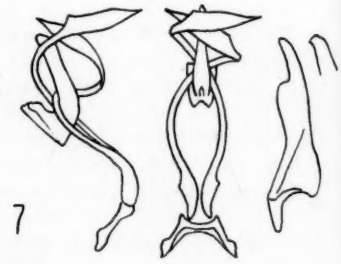


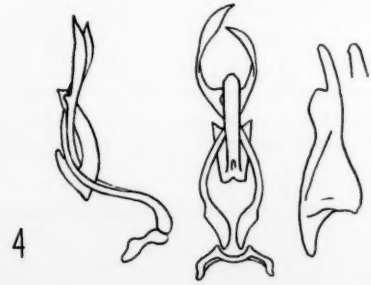


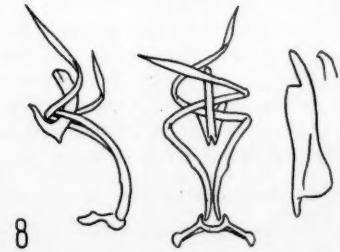












Key to Males of Canadian Species of *Cloanthanus*

1. Fore wings blackish; paraphyses slender, not expanded toward their apices (Fig. 6). Southern Ontario ..... *frontalis* (Van D.)

   Fore wings usually not blackish, or, if blackish, then paraphyses each broadly expanded at apical third 2

2. Paraphyses each long and slender with a long, slender lateral process beyond middle. Quebec ..... *fulvus* (Osb.) (*collaris* S. & DeL.)

   Paraphyses each expanded and flattened beyond middle, bifid at apex only, or not bifid 3

3. Paraphyses long, slender, not or hardly expanded, not twisted around shaft of aedoeagus 4

   Paraphyses each expanded and flattened beyond middle, twisted around shaft of aedoeagus, or both 7

4. Paraphyses strongly recurved at apical third; shaft of aedoeagus shorter, in lateral view not distinctly narrowed toward apex; pygofer without excavation on ventral margin 6

   Paraphyses not strongly recurved; shaft of aedoeagus longer, in lateral view distinctly narrowed toward apex (Fig. 2); pygofer with excavation in ventral margin 5

5. Vertex about one and one-half times as long as wide between the eyes. Nova Scotia, Prince Edward Island, New Brunswick, Quebec, Ontario, Manitoba, Saskatchewan, Alberta, and British Columbia ..... *acutus* (Say) (*modestus* Stål, *filamentus* DeL., *tenuis* DeL.)

   Vertex about twice as long as wide between the eyes. British Columbia ..... *acutus* (Say) var. *dubius* (Van D.)

6. Paraphyses each bifid at apex (Fig. 1). Nova Scotia and Ontario ..... *sarissus* n. sp.
   Paraphyses each sharply pointed at apex, not bifid (Fig. 5). Quebec and Manitoba ..... *cinnamoneus* (Osb.)

7. Paraphyses each with a broad lateral projection beyond middle (Fig. 4) Ontario and Quebec ..... *magdalensis* (Prov.) (*obscurus* Osb., *carolinus* Lathrop, *vaccinii* DeL.)

   Paraphyses not as above 8

8. Paraphyses each broadly expanded toward apex; aedoeagus narrowed toward apex in ventral view; general colour not pale greenish-fulvous 9

   Paraphyses less broadly expanded toward apex, twisted around aedoeagus; aedoeagus not narrowed toward apex in ventral view (Fig. 8); general colour pale greenish-fulvous. Ontario ..... *angustatus* (Osb.)

9. Dorsum fulvous; vertex less than one and one-half times as long as wide between the eyes; length 5.5-6.0 mm.; paraphyses short and broad. British Columbia ..... *oregonensis* (Baker)

   Dorsum and vertex not as above; length not exceeding 5.5 mm. 10

10. Paraphyses stout, each with a large, triangular, flattened expansion near apex (Fig. 3). Quebec, Ontario, Manitoba, Saskatchewan, and British Columbia ..... *latus* (Baker) (*cuprescens* Osb.)

    Paraphyses, longer and more slender, each with the expansion near apex less broad, not triangular (Fig. 7). Quebec ..... *argutus* DeL. (*hastus* DeL., *lanceus* DeL.)

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Figs. 1-8. Aedoeagi, paraphyses, and connectives, lateral and ventral views, and styles of *Scaphytopius* (*Cloanthanus*) spp. 1, *S.* (*C.*) *sarissus* n. sp.; 2, *S.* (*C.*) *acutus* (Say); 3, *S.* (*C.*) *latus* (Baker); 4, *S.* (*C.*) *magdalensis* (Prov.); 5, *S.* (*C.*) *cinnamoneus* (Osb.); 6, *S.* (*C.*) *frontalis* (Van D.); 7, *S.* (*C.*) *argutus* DeL.; 8, *S.* (*C.*) *angustatus* (Osb.).

A Method of Measuring Pollinator Populations on Field Crops

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The seed production of many field crops, and in particular of legumes, depends to a large degree upon the number of pollinating insects present in the field during the blooming period. A study of the various factors affecting seed production requires, among other things, a knowledge of the population of pollinating insects present, and a ready means of comparing pollinator populations from one field to another. To obtain this information some means must be employed to count and classify the pollinating insects in the field.

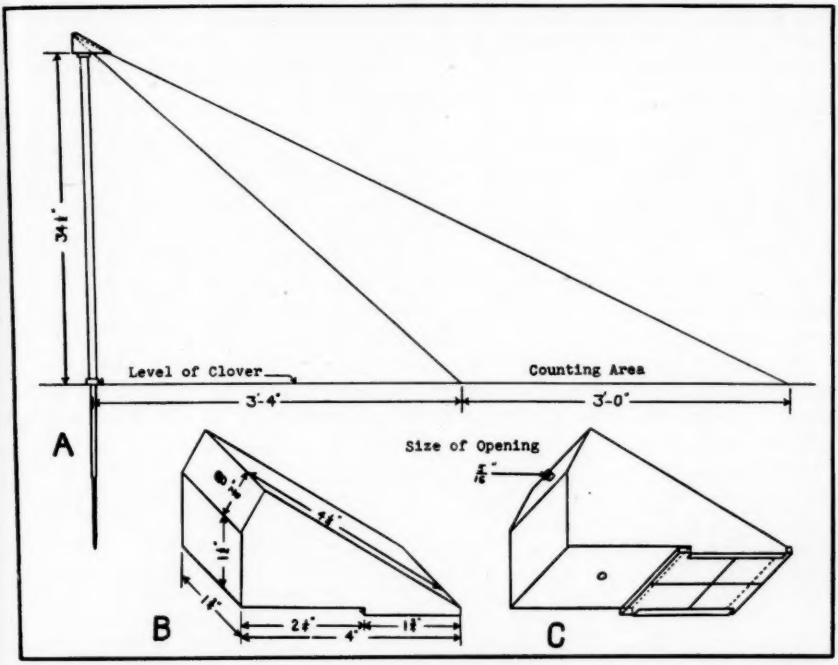
Previous workers have relied mainly on two methods to obtain this information. Linsley (1946) describes a sweep method whereby samples of the pollinating insects are captured in an insect net. This method is easily carried out and does permit positive identification of the insects captured. Windy days do not interfere with the counts and it is possible to obtain a good coverage of the field. However, it does disturb the pollinator population, and where repeated counts are desired in rather limited areas this may be an objectionable factor. Legume fields are rarely absolutely free of weeds or other clovers, and it is always possible that some of the pollinators captured in the net may not have been working on the crop under study. In addition, certain quick flying insects may not be captured in numbers representative of their true population. This method does not give the population per unit area of the field, thus making it difficult to accurately estimate the total pollinator population in a field.

A second means employed to evaluate pollinator populations is to mark off small unit areas randomly scattered throughout the field, and take counts of the insects visiting these plots. Vansell and Todd (1946) used square yard plots on alfalfa, and Jamieson (1950) used two square yard plots on red clover for pollinator studies. While this method is an improvement upon the sweep method for prolonged detailed observations, it still has its limitations. For accurate observation the plots must be rather limited in size. It is often impossible to have enough of these small areas marked off throughout the field to give as complete a coverage as desired—particularly in the larger fields. When records are to be taken over the entire blooming period of a clover crop, care must be taken not to tramp down the clover surrounding the measured plot, thus leaving an island of bloom which might appear more attractive to pollinating insects. Other factors which are not too well understood, but which may influence counts taken by this method, are the rather limited foraging areas of field bees, as reported by Butler (1943) and Singh (1950), and the possible influence of stakes and strings upon the normal flight of foraging bees. In addition, staked-off areas may at times interfere with the application of insecticides to crops in bloom.

In an attempt to overcome some of the objections inherent in the above two methods, a simple portable type of pollinator counter was devised whereby a large number of square yard counts could be taken in a relatively short time. This permits a very complete coverage of the field under study with a minimum of disturbance to the insect population.

Construction of Counter

The counter developed for this work is shown in Fig. 1 (A). It consists of a view-finding unit, details of which are shown in Fig. 1 (B & C), mounted at the



top of an extensible metal shaft. The viewer may be fitted with a plastic grid which will divide the projected square yard into quarters to facilitate counting. The base of the shaft is provided with a spike which may be thrust into the ground to steady the instrument while each count is being taken.

Operation

The spike is driven into the ground so the instrument is in an upright position and the ring on the shaft is then adjusted to the height of the crop. This will place the view finding unit 34½ inches above crop level, at which height one square yard of bloom will be outlined, with its near edge approximately 40 inches distant. At this distance pollinating insects may be readily observed yet not disturbed. Blossom counts as well as insect counts may be recorded with this instrument. Up to 45 counts per hour may be taken by each observer.

Counts may be taken 10 to 20 paces apart along paths laid out across the field, the number of paths depending on the size of the field and the coverage desired. The counter should be directed at an angle of 45° to the right or left of the path ahead of the observer. Care should always be taken that the observer's shadow does not fall upon the area being counted.

Duration of Counts

In studies of pollinator populations, an instantaneous rather than a cumulative count will give the most useful information. However, since it is often difficult to obtain an instantaneous count with any degree of accuracy, we have adopted a count of approximately 10 seconds duration. Insects working on a crop such as red clover are often on the far side of the clover head or on the underside of the blossom where they cannot be seen by the observer. By observing the area for 10 seconds these insects will have an opportunity to move, thus revealing

their presence. An insect a few inches away may have time to move into the observation area, but those already in the area will not have time to move out and in again and thus be counted twice. It is felt that this method gives a reasonably accurate measure of the instantaneous population.

Limitations

As designed this instrument is capable of being used on crops up to 3 feet in height. However unless some sort of a standing block is used, 25 to 30 inches will be the height limit for the average observer. Most legumes with the exception of sweet clover lend themselves readily to this type of observation.

Windy weather may interfere with counts. However pollinator populations frequently fall off on windy days, and the few insects remaining can usually be spotted when they fly. Very few days have been encountered during the past two summers when counts could not be taken because of the wind.

Positive insect identification cannot be made. Insects can, however, be readily classified as honeybees, bumble bees, other native bees, and other insects, which is suitable for most pollinator studies. Counts may be supplemented by additional collections where species identification is desired.

This instrument was developed to aid in pollination studies as part of the programme of the Legume Research Committee in Ontario. In its final form, it was designed and constructed by A. H. Northcott, instrument maker, of 16 Gordon Street, Guelph, Ontario. Drawings through the courtesy of E. W. Walpole, Department of Agricultural Engineering, Ontario Agricultural College.

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Analysis of a Population Sampling Method for the Lodgepole Needle Miner in Canadian Rocky Mountain Parks[1]

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Introduction

General.—The purpose of this paper is to analyse a sampling method devised to assess larval populations in an outbreak of the lodgepole needle miner, *Recurvaria milleri* Busck (Busck 1914, Hopping 1945).

The problem of developing an adequate sampling method is intimately concerned with the life-history of the insect, the region of the outbreak and the nature of the forest stand in which the outbreak occurs. In sampling most defoliator populations the problem is made more difficult by external feeding and wandering habits, hence it is usually done in some relatively inactive stage at a fixed time. de Gryse (1934) describes the problems inherent in sampling these insects. The needle miner, however, is fixed in its location for most of its life-cycle and is therefore readily obtainable for study. The problem here

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is reduced to a statistical one, that of obtaining an acceptable sample i.e. within suitable error limits with due regard for existing variables.

Life History of the Insect

The needle miner in the Canadian Rocky Mountain parks has a two-year life-cycle. In the even years 1952, 1954, etc.), the adults emerge in July, the eggs are laid in August and hatch in August or September. Each larva immediately enters a needle in which it spends the first winter. The following spring, the miner commences feeding some time in May and completes mining the first needle. The transfer to the second needle takes place normally in late July or August but climatic conditions cause great variability in transfer dates. The larva overwinters in the second needle and in the following spring, again an even year, the larva transfers to a third needle. It completes mining this by the middle of June, pupates, and the moth emerges three to four weeks later. From the above, it is obvious that the best time for intensive sampling is in the odd year prior to or following the transfer. Sampling could be done in the moth flight year but the sampling time is restricted.

Description of the Region

The needle miner outbreak is concentrated in three national parks: Banff, Yoho, and Kootenay. The terrain is mountainous, the general character of the mountains being steeper and more rugged on the east side than on the west. These parks are similar in that there is a relatively narrow valley in each with steep, high, sides formed by mountain ranges, often up to 10,000 feet in height. In Banff National Park the direction of the valley is north-west; in Kootenay, south; in Yoho, due west. The Bow Valley in Banff National Park has an almost pure stand of lodgepole pine with isolated small patches of spruce, alpine fir and Douglas fir. These stands vary in age from 35 to 200 years, although most of them are about 75 years old. All lodgepole-pine stands in this region are a fire succession type. The mixed stands in Yoho and Kootenay are composed of lodgepole pine, spruce, and alpine fir of varying age, from 50 years to overmature.

History of the Outbreak

The outbreak was first noticed in 1942 (Hopping 1945). The infestation was then restricted to a band between the 5,000 and 6,500 foot elevations. It was confined largely to Banff National Park and covered an area of approximately 50 square miles. By 1944, the area of the outbreak was approximately 300 square miles extending into all three adjacent parks (Hopping 1946). In the two succeeding moth flight years, the infestation increased in intensity and extended to practically all areas within Banff National Park and adjacent parks, wherever there were extensive pine stands.

During the winter of 1949-50 a high mortality of late-instar larvae occurred in Banff National Park, reducing the infestation there to a level where discoloration of the pines was less evident than in 1948. The outbreaks in Yoho and Kootenay remained at approximately the same level.

Materials and Methods

Sampling Procedure

The sampling technique evolved at the beginning of the investigation has been changed only in minor details. In the beginning, four branch tips were taken from the upper third of the crown, one from each directional vector. A similar sample was taken from the lower crown. Each branch tip was cut back to include the 5-year-old needles, since the lodgepole pine in this region does

not usually retain older foliage. These samples were obtained either by climbing the tree or by cutting it down. Later, an aluminium sectional pruning-hook was obtained that permitted upper crown samples to be taken from the ground. The taking of samples from the four directional vectors was discarded in 1951.

In early sampling, a trained observer attempted to pick 'average' trees and 'average' tips when sampling. This also was changed in 1951; the only decision the sampler had to make was that of choosing sound tips.

In 1949, the first year of comprehensive sampling, seven areas were visited, four altitude levels at each (at valley bottom and at 500-foot contour levels). At first, five trees were sampled at each level, but the time and staff available at that time necessitated a reduction in the number of trees to three. The same procedure was followed in 1950. In 1951, however, due to the severe reduction in numbers of miners and to conclusions reached in the analysis of the 1949 data, only one area was done intensively and the results form the basis for this paper. The altitude levels were reduced to three, with a 750-foot interval. Forty trees were sampled at valley bottom, 35 at the 750-foot level and 30 at the 1,500-foot level.

Preliminary Analysis of Data

The data of 1949 and 1950 were analyzed using normal statistical methods. The analyses were based on only three trees per level with the exception of two areas, where five trees were sampled. Normalcy was established; analysis of variance was applied to the raw data. Altitude levels, branch tips, directional vectors, crown levels, and all areas were compared for differences.

1951 Analysis

The analysis of the 1951 data was based on many more trees than in previous years. Also the raw data were not used but subjected to a transformation, $X=\sqrt{n+1}$. Normalcy was established in the lower two altitude levels and in the combined figures of all three levels. The standard and percentage errors were calculated for each sampling level using 5 trees, 10 trees, 15 trees, etc. This determined the number of trees necessary to give an adequate sample within any error limit set. This was done for upper and lower crowns separately. The data were then analysed for variance using Snedecors' 'F' test. Altitude levels, crowns, and trees at each altitude level were compared for differences.

The Variance Component Technique was applied to valley bottom data to determine the most satisfactory number of branch tips to be taken from each tree. The formula used was:

$$\text{S.E.}_{\bar{x}} = \sqrt{\frac{\sigma_s^2 + n\sigma_T^2}{2nT}}$$

where:

σ_s^2=the mean square derived from the analysis of variance within trees, within crowns.

σ_T^2=the mean square from the analysis of variance between trees, within crowns.

n=the number of branch tips per crown level.

T=the number of trees sampled.

Results and Discussion

The analyses of the 1949 data yielded only the most general results. From this analysis it appeared that significant differences in needle-miner populations existed between altitude levels, between trees, and between certain areas. There was contrasting evidence on differences between crowns. The errors calculated from the samples were so large as to cast doubt on the validity of any conclusions

drawn and the population estimates do not warrant inclusion in this paper. It was only too evident that three or five trees was insufficient for any adequate sampling procedure.

The analysis of the 1951 data clarified the issue. With a total of 105 trees sampled, normalcy was established for the sampling area in Yoho National Park. When tests were applied to each level, however, the highest or 1,500-foot level was found not to have a normal distribution. Strictly speaking then, the conclusions drawn from the analysis apply only to valley bottom and the 750-foot level. This is not too serious a matter as the highest level has always had a light population in all areas sampled in the past few years. Moreover, in the national parks concerned, the 1,500-foot level is close to timberline and the forest at this altitude is frequently thin and of mixed composition. This sampling level could well be omitted in an intensive sampling program; a visual survey would be adequate.

The population estimates (Table 1) are the average number of larvae per 5-year branch tip. As there are from 60 to 100 available needles per tip, the percentage infestation can thus be easily estimated.

To obtain absolute populations in trees or stands for any particular area, it would be necessary to establish the relationship of number of branch tips to height-classes. This was done by Graham and Shepherd (1951) for the Eisenhower region in the Bow Valley.

TABLE I

AVERAGE NUMBER OF LARVAE PER TIP

Sampling level	Upper Crown	Lower Crown
Valley bottom	25.6 (40)	14.3 (40)
750 foot	15.1 (35)	7.3 (35)
1,500 foot	2.7 (30)	0.8 (30)

The number of trees upon which the estimate is based is indicated in brackets.

The percentage errors (Table II) were calculated from the standard error of the mean ($S.E._{\bar{x}} = \frac{\sigma}{\sqrt{n}}$) by the formula:

$$\text{Percentage error} \quad \frac{2\ S.E._{\bar{x}}}{\bar{x}} \times 100$$

TABLE II

SUMMARY OF PERCENTAGES ERRORS OF POPULATION DATA – YOHO, 1951

No. of Trees	Valley bottom		750-foot level		1,500-foot level	
	Upper Crown	Lower Crown	Upper Crown	Lower Crown	Upper Crown	Lower Crown
5	20.15	30.72	8.97	18.80	19.42	29.14
10	13.80	21.66	10.13	16.81	12.20	18.89
15	9.22	14.13	12.04	12.46	13.29	13.86
20	8.58	15.87	9.99	10.24	10.81	10.84
25	9.58	14.21	9.4	10.28	9.02	12.51
30	9.02	12.23	8.18	10.72	9.24	10.87
35	8.31	10.93	7.36	9.69		
40	7.43	10.23				

The use of the transformation compensates adequately for the small size of many of the samples. From Table II the number of trees required for any set error can readily be determined. This will save time by reducing over-sampling. For example, at valley bottom for the upper crown, 15 or 20 trees would give adequate results but in the lower crown, 40 trees would be required to achieve results within a set error of 10 per cent.

The analysis of variance is shown in Table III.

TABLE III

ANALYSIS OF VARIANCE – YOHO, 1951

Source	Degree of Freedom	Mean Square
Between altitudes	2	128.7**
Between crowns		
Valley bottom	1	22.33**
750 foot level	1	20.07**
1,500 foot level	1	5.46**
Between trees		
Valley bottom	29	2.32**
750 foot level	29	0.9*
1,500 foot level	29	0.2
Within	87	0.6

**Significant at the 1% level
*Significant at the 5% level

The difference between the number of larvae in the upper crown and the lower crown is significant so they must be treated separately when sampling to avoid minimizing the seriousness of an outbreak. Moreover, the difference between trees is found to be significant beyond the 1 per cent level at valley bottom, barely significant at 5 per cent at the 750-foot level, and not significant at the 1,500-foot level. This is no doubt due to the lower populations at the higher levels.

The conclusions of the analysis are that by applying a transformation of $X=\sqrt{n+1}$ to the raw data, population estimates can be made within set error limits and also that a pattern for sampling of a needle-miner outbreak can be formed.

Table IV presents the results of the application of the variance component technique to valley-bottom data.

TABLE IV

COMPARING THE EFFICIENCY OF VARIOUS COMBINATIONS OF BRANCH TIPS AND TREES IN SAMPLING NEEDLE MINER POPULATIONS

No. of branch tips per crown level	50	8	4	2	1
No. of trees	9	10	12	16	24
Total No. of tips examined to give accuracy within 10 per cent of the mean (both crown levels)	900	160	96	64	48

A discrepancy will be noted in the number of trees required in Table IV and those obtained in Table II. For example, at 4 tips per trees the variance component technique indicates that only 12 trees are required to give a population

estimate correct within 10 per cent of the mean. Table II indicates between 10-15 trees for the upper crown and 40 for the lower crown. This discrepancy arises from differences in the two techniques. The discrepancy is less in Table II if the percentage errors of upper and lower crown are averaged. In the variance component technique the two are combined and result in a lower standard error. In actual population sampling, more trees (or tips) would probably be required to obtain an estimate within 10 per cent for lower crown alone.

The decision facing any sampler in view of the above is whether it takes more time for the examination of many branch tips from fewer trees or vice versa. With the proper sampling equipment, the sampling of a greater number of trees with fewer tips to examine is obviously the best. However, where the trees have to be cut down or climbed to obtain upper-crown samples, some other combination would prove more efficient.

Summary

An adequate sampling method has been devised for the lodgepole needle miner as follows: the average number of larvae per branch tip (including five years' needles) is accepted as the infestation unit; four branch tips are taken from two crown levels in each tree, the average number per branch tip per tree being calculated for each crown level. In the population now present in Yoho National Park, to obtain results within a 10 per cent error (computed from the standard error of the mean) 40 trees were sampled at valley bottom, 35 at the 750-foot level, and 30 at the 1,500 level. Application of the variance component technique indicated that sampling fewer trees with more branch tips or more trees with fewer tips would give comparable results. Transformation of the data was required so that analysis of variance could be applied. There is a significant difference in degree of infestation between altitude levels, between trees at valley bottom and the 750-foot level, and between crown levels. For practical purposes the lower-crown samples could be eliminated and the measure of the outbreak taken as the average number of larvae per tip in the more vital upper crown. Fewer trees would be required for this estimate. Progress of an outbreak could be determined by yearly investigations of this type.

Acknowledgments

The work in population sampling was begun in 1948 under supervision of Mr. G. R. Hopping, Officer-in-Charge, Laboratory of Forest Zoology, Calgary. The general sampling method was drawn up in 1949 by Mr. Hopping, Dr. K. Graham, University of British Columbia, and the author. Mr. Hopping and Dr. Graham have assisted in the work every season since that time. Mr. G. B. Oakland, Head of the Biometric Unit, Science Service, Ottawa, greatly contributed to the statistical analysis and presentation of the data.

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Book Review

A Guide to Microscopy

"The Intelligent Use of the Microscope" by C. W. Olliver (Chapman and Hall, London, 1951: $3.25 from British Book Service, (Canada) Limited, Kingswood House, 1068 Broadview Avenue, Toronto, 6) is a work of 191 pages with 59 illustrations in the text, written, according to its author, for beginners by a non-expert who often understands the difficulties and problems of novices better than the expert. A short introductory chapter leads to a short account of optical theory, followed by a discussion of "numerical aperture" and its relation to the problem of the resolving power of the microscope. The author gives a detailed account of microscopical components and accessories and advises on the selection of equipment. He then deals with illumination under the several headings of transmitted dark-field and reflected illumination. The remaining chapters are devoted to the actual use of the microscope, measurements and counts, filters, photomicrography and special apparatus. The final chapter gives a short account of phase microscopy.

All entomologists have been accustomed since their initiation into science, to the use of the microscope. However there are probably not many who have had a formal course of instruction in microscopical optics or even in the practise of microscopy; and all those who have not will find the study of Mr. Olliver's little book both interesting and profitable. This reviewer feals that Mr. Olliver, a Fellow of the Royal Microscopical Society and an Associate Member of the Institute of Electrical Engineers, is much more of an expert than he may realize, and that entomologists who know their microscope only by use and experience will find spots where more ample explanations would have been helpful. Nevertheless, much that is of great value can be gleaned from its pages and it can be unhestitatingly recommended as a useful handbook and work of reference.

W. R. THOMPSON

***The Heleidae of California*, by W. W. Wirth. University of California Publications in Entomology, Vol. 9, No. 2. Pp. 95-266, $2.00, 1952.**

Not since 1915 has a revision of all the Heleidae (=Cerato-pogonidae) of any part of North America been published. The classification has been altered so much and so many additional characters are used that this is really the first modern revision; it is a pleasure to see it done in such a competent manner. The study was preceded by intensive collecting by the author and his associates; abundant material was therefore available.

The bulk of the work is on the taxonomy of the adults; of the 110 forms treated, 51 are described as new; only three of these were described from single specimens. Approximately 300 figures illustrate most of the characters useful for identification, as well as some of the variations encountered. Keys to species and to higher groups, a list of synonyms for each species and genus, and a checklist are included. A few minor changes are made in application of generic names and in the supergeneric classification. The value of the work to workers outside California is increased by the inclusion of a summary of the distribution outside California of each species.

Short sections on economic importance of the group, on methods of collecting, preservation, and study, on morphology of the adults, and on bionomics of the adults and larvae are included. A somewhat longer section deals with the larvae and pupae; it includes a key to genera, and figures and brief descriptions of larvae and/or pupae of 17 Californian species.

J. R. VOCKEROTH

***Cynipoidea (Hym.)* 1905-1950: By Lewis H. Weld, 1952. 350 pp., paper cover. Privately processed. For sale by the author at 6613 N. Washington Blvd., Arlington, Va., U.S.A. Price $5.00.**

This volume supplements the Dalla Torre and Kieffer monograph on the Cynipoidea of the world (Das Tierreiche, pt. 24, Cynipidae, 1910), which covers the period before 1905.

The general arrangement is excellent, although it is difficult to find the statement that the keys are based on females (p. 122), the definition of the term *foliiform* (p. 122), the illustrations of the general taxonomic terms (pp. 142-3), and the list of museum abbreviations (p. 261). The bibliography of the systematic literature since 1904 is linked with annotated lists of the newer taxonomic and manuscript names, and with references to descriptions of alternate generations and to some redescriptions. Each new species since 1904 is placed generically and the transfers to other genera are recorded. Each major group and genus is discussed in detail, the genera having annotated lists of the species described since 1904 and the present generic placings. Sixteen genera are newly synonymized and many new combinations made.

The keys run to the generic or subgeneric level, although keys to species are given for the U. S. Ibaliidae and for some Liopteridae. The keys are profusely and clearly illustrated. They include several errors (these have been checked with the author):— the last half of couplet 1 on p. 124 should lead to 27 and the last half of couplet 51 on p. 135 to 59, not 57; the last half of couplet 95 on p. 145 should read: "No median carina on propodeum and without the above combination of characters ..... 96". Several other couplets have the last half missing, being used to amplify the generic or subgeneric descriptions.

This revision is based upon the author's unique knowledge of the types in Europe and North America, supplemented by many years of collecting and classifying. One result is the partial arranging of the Cynipinae in natural groups; another is that the keys include various sexual and agamic forms, and many segregates within genera. The book is a very welcome step forward in the study of this fascinating and difficult superfamily.

O. PECK

***Guide to the Insects of Connecticut. Part VI. The Diptera or True Flies. Fifth fascicle: Midges and Gnats. Tendipedidae (Chironomidae)*, by O. A. Johannsen and Henry K. Townes; *Heleidae (Ceratopogonidae)*, by O. A. Johannsen; *Fungivoridae (Mycetophilidae)*, by Frank R. Shaw and Elizabeth G. Fisher. Pp. 255; 38 plates. Connecticut State Geological and Natural History Survey Bulletin No. 80. 1952.**

This latest number in an already outstanding series of publications is particularly welcome as the families dealt with are among the most neglected in the whole order. Except for a recent revision of the tribe Tendipedini, no major work on the eastern North American species of any of the groups treated has appeared since 1915. The value of the work is greatly increased by the inclusion of all the species of the northeastern United States (roughly the area north of North Carolina and east of the Mississippi.)

One of the more important features of the work is the adoption of the Meigen 1800 names throughout. Although the key to families in Fascicle I used the Meigen 1803 names, little confusion should result, as the 1803 names are included as synonyms in this fascicle. The change is significant, however, as general works of this sort so far published in North America have almost completely excluded the 1800 names; since this series will undoubtedly remain a

standard reference work for many years, the use of these names may do much to bring about their adoption by entomologists in general.

Except for the section on Tendipedini by Dr. Townes, the work consists almost entirely of keys to species with brief summaries of distribution. The figures are not numerous, and with a few exceptions they are of more value for generic than for specific determination. A number of changes are made in nomenclature and in the arrangement of genera and supergeneric groups in order to have a system of classification similar to that adopted by European workers.

The section on Tendipedini is in rather a different category. It is an abridgment of the revision of the tribe published by Townes in 1945; it is based on all the material available at that time, and includes adequate descriptions and figures for all the species treated.

One is left with the feeling that the treatment of these groups, again excepting the tribe Tendipedini, is very incomplete—that many of the described species are poorly known and that many more are yet to be described—in short, that a comprehensive revision of the various groups is necessary. But as a survey of the work already done, and as a stimulus to further collecting and study, it should be invaluable.

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